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ELECTRONICS ORIGINAL ARTICLE

A Novel methods of ICI self Cancellation Scheme in OFDM System

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ABSTRACT

In OFDM System the Frequency offset in wireless communication systems distort the Orthogonality between subcarriers resulting in Inter Carrier Interference(ICI).This Paper presents a new scheme for ICI self cancellation which is simple and convenient technique. It utilize data allocation and combining of ($\lambda_{so,}\ \mu_{so}$) on to a pair of symmetrically placed subcarriers to reduce the ICI. In proposed scheme we are maximizing CIR performance for a normal frequency offset ε . In this method the CIR performance is about more than 20dB better than that of normal OFDM for Small values of frequency offset ε and having same bandwidth efficiency for larger Doppler frequency. Simulation results show that comparing proposed scheme with standard OFDM system and conventional ICI self cancellation. In simulation results we found that the performance of proposed scheme is better than the standard OFDM system and conventional ICI self cancellation.

Keywords: **ICI, CIR, OFDM, CFO, etc…**

I. INTRODUCTION

The orthogonal frequency division multiplexing (OFDM) is a form of multi-carrier modulation technique OFDM transmission [1] achieves high spectral efficiency by splitting a high-rate data stream into several lower-rate streams which are mapped onto mutually overlapping subcarriers and transmitted simultaneously. By inserting a cyclic prefix of length larger than the maximum channel delay spread, the intersymbol interference can be easily avoided and the demodulation of OFDM signals can be realized by a one-tap equalizer. Motivated by these attractive properties, OFDM has been widely adopted in transmission standards such as Digital Video Broadcasting (DVB) [2], Wireless LAN, WiMAX, and so on.

The disadvantages of an OFDM system [5]:

1. Higher transmitter output back off is required in comparison to a single carrier system, because of the high peak-to-average power ratio of an OFDM system.
2. As a parallel transmission technique, OFDM is more sensitive to carrier frequency offset (CFO) and tone interference than that of a single carrier system.

CFO introduces the ICI which degrade the overall system performance The ICI effect can be effectively mitigated by the conventional ICI self-cancellation schemes. The average carrier-to-interference power ratio (CIR) [3] is used as the ICI level indicator, and a theoretical CIR expression is derived for the proposed scheme.

In ICI self cancellation scheme the performance degrades at high frequency offset, in conjugate cancellation scheme[10] which improve CIR at very low frequency offset and its performance decreases as carrier frequency offset greater than 0.25, in Phase Rotated Conjugate Cancellation (PRCC) it requires continues carrier frequency offset(CFO) estimation and feedback circuitry which increases the hardware complexity[9]. In this paper we propose a sub optimal approach to find sub optimal values

($\lambda_{so,}$ μ_{so}) in which data is modulated at two symmetrical placed sub carriers i.e, k[th] and N-1-k[th] and utilizes a data allocation of (1,- $\lambda_{so,}$) and subcarriers are combine with weights (1,- μ_{so}). ($\lambda_{so,}$ μ_{so}) are suboptimal values and are independent of normalized frequency offset ε .it does not require any CFO estimation or feedback circuitry and hence eliminates the requirement of complex the hardware circuitry.

The rest of the paper is organized as follows: the mathematical model of a regular OFDM system and ICI self cancellation scheme are described in Section II. Analysis of the proposed system is discussed in Section III. Section IV presents the simulation results and some discussion on them. Finally, some conclusions are given in Section V.

II. STANDARD OFDM SYSTEM

A. OFDM System model

The discrete time baseband OFDM symbol after the IFFT block at the transmitter can be expressed as

$$x[n] = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X(k) e^{j2\pi nk/N}, \; n = 0,1,2.....N-1 \tag{1}$$

here N is the total numbers of subcarriers and X(k) is the modulated data symbol transmitted on k[th] subcarrier .At the receiver, the time-domain received signal suffering from a frequency offset and an Additive White Gaussian Noise (AWGN) can be written as

$$y[n] = x[n] e^{j\frac{2\pi\varepsilon n}{N}} + w[n], \quad n = 0,1,2.......N-1 \tag{2}$$

ε represents the frequency offset normalized by the frequency spacing of two subcarriers and w[n] is a zero-mean AWGN. After the Fast Fourier transform (FFT) block, the frequency domain signal at the k [th] subcarrier is given as

$$Y(k) = X(k)S(0) + \sum_{l=0, l\neq k}^{N-1} X(l)S(l-k) + W(k), \quad k = 0,1,2,..N-1 \tag{3}$$

Where W (k) is the DFT of w[n] and S (l-k) is referred as ICI weighting coefficient i.e

$$S(l-k) = e^{\left(j\pi(l+\varepsilon-k)\left(1-\frac{1}{N}\right)\right)} \frac{\sin(\pi(l+\varepsilon-k))}{N\sin\left(\frac{\pi}{N}(l+\varepsilon-k)\right)} \tag{4}$$

The CIR at the k[th] subcarrier is

$$CIR_o = \frac{|S(0)|^2}{\sum_{l=0, l\neq k}^{N-1} |S(l-k)|^2} \tag{5}$$

from the above equation the CIR as a function of the normalized frequency offset ε and N, however CIR varies little as a function of N therefore CIR only depend on normalized frequency offset ε

The block diagram of the above description is given below

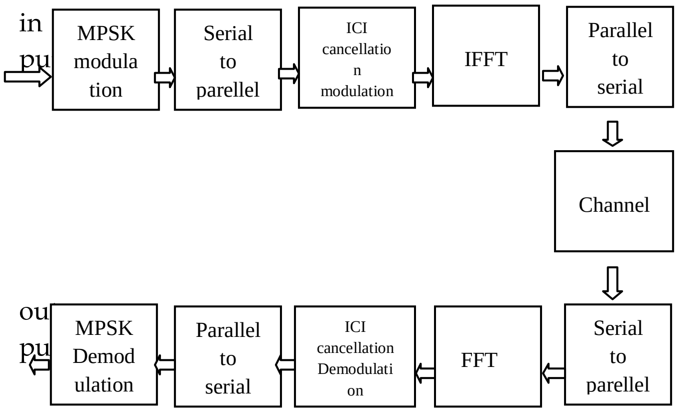


Fig1. Block diagram of the proposed scheme

B. PHASE SHIFT KEYING

The most popular M-PSK modulation techniques include BPSK, QPSK, 16-PSK and 256-PSK.

Quadrature Phase Shift Keying (QPSK)

Quadrature Phase Shift Keying has twice the bandwidth efficiency of BPSK, and the phase of the carrier takes on one of four equally spaced values, such as 0, Π/2, Π and 3Π/2, where each value of phase corresponds to a unique pair of message bits.

The QPSK signal may be defined as

$$S_{QPSK}(t) = \sqrt{\frac{2E_S}{T_S}} \cos\left[2\pi f_C t + (i-1)\frac{\pi}{2}\right]$$

$$\text{for} \quad 0 \le t \le T_b \qquad i = 1,2,3,4$$

Where T_s is the symbol duration and is equal to twice the bit period. In QPSK two successive bits are combined this combination of two bits forms four distinct symbols. When symbol is change to next symbol the phase of the carrier changed by 45º (π/4 radians). The table (1) shows symbol and their phase shifts

TABLE-1
RELATION BETWEEN THE INPUT SYMBOLS AND THE PHASE SHIFTS

Information Bits Mi, Mq	Phase Shifts π
11	π/4
01	3π/4
00	-3π/4
10	-π/4

C. ICI self cancellation scheme

i) Modulation

From the conclusion of Section II, it is impossible to reduce the ICI unless the ε value is decreased. but for smaller values of ε bandwidth efficiency will be reduced since symbol length is reduced therefore guard interval will be large.

So the idea of ICI cancellation [4] is, for the majority of subcarriers the difference between symmetrically placed ICI coefficients are very small [7]. Therefore if a complex data pair ex:(a,-a) is modulated onto two symmetrically placed subcarriers ,then the ICI generated by these subcarrier will be significantly cancelled out.

Assume that the transmitted data symbols are constrained

$$X(N-1)=-X(0),\dots\quad X(N-1-k)=-X(k)$$

so the k^{th} subcarrier is repeated at the N-1-k^{th} subcarrier with opposite polarity.

The received data signal at the k^{th} subcarrier is given by

$$Y'(k)=\sum_{l=0}^{\frac{N}{2}-1}X(l)(S(l-k)-S(l+1-k))+W(k) \tag{6}$$

and on N-1-k^{th} subcarrier

$$Y'(N-1-k)=\sum_{l=0}^{\frac{N}{2}-1}X(l)(S(l+k+1-N)-S(k-l))+W(N-1-k) \tag{7}$$

here the ICI coefficient is defined as

$$S'(l-k)=S(l-k)-S(l+1-k) \tag{8}$$

from the equation(6), it takes only half of the N values, so the number of interference signals are reduced to half and the ICI signals are much smaller than in equation (3) so the number of ICI signals and amplitudes of ICI coefficients have been reduced, such modulation is called ICI cancelling modulation.

ii) Demodulation

In this each signal at the N-1-k^{th} subcarrier is multiplied by " -1" and then summed with the one at the k^{th} subcarrier. Then the resultant data sequence is

$$Y''(k)=Y'(k)-Y'(N-1-k) \tag{9}$$

thus CIR of conventional ICI self cancellation scheme can be written as

$$CIR_c=\frac{\left|-S(-N-1-2k)+2S(0)-S(1-N+2k)\right|^2}{\sum_{\substack{l=0\\ l\neq k}}^{\frac{N}{2}-1}\left|S(l-k)-S(N-1-l-k)-S(l+k+1-N)+S(k-l)\right|^2} \tag{10}$$

III. PROPOSED SCHEME

In general at the transmitter a data allocation (1,-λ) is used at symmetrical subcarriers i.e

$$X(N-1)=-\lambda X(0),\dots\quad X(N-1-k)=-\lambda X(k)$$

now the received data at the k^{th} subcarrier is

$$Y'(k)=\sum_{l=0}^{\frac{N}{2}-1}X(l)(S(l-k)-\lambda S(l+1-k))+W(k) \tag{11}$$

so the received data with combination of k^{th} and N-1-k^{th} subcarriers with $(1,-\mu)$

$$Y''(k)=Y'(k)-\mu Y'(N-1-k) \tag{12}$$

thus the CIR of this optimal scheme is

$$CIRp=\frac{\left|-\mu S(-N+1+2k)+(1+\lambda\mu)(S(0)-\lambda S(-1+N+2k)\right|^2}{\sum_{\substack{l=0\\ l\neq k}}^{\frac{N}{2}-1}\left|S(l-k)-\mu S(-N+1+l+k)-\lambda S(-l-k-1+N)+\mu\lambda S(k-l)\right|^2}$$

…(13)

the optimal values λ *and* μ have been found by using Nelder Mead Simplex Algorithm(NMSA)[8]. These optimal values are calculated for $\varepsilon\in[0.03,0.25]$ at a very small interval of $\nabla\varepsilon$ which results in maximize the CIR for given ε. but the drawback is for every ε ,there is unique optimal values and always this require a continuous CFO estimation this increase in hardware complexity for each pair of optimal values the CIR has been calculated which forms a CIR $_{vxv}$

matrix[6] i.e, the elements in the matrix as the form like $CIR_p(\varepsilon_v, \lambda_{ov}, \mu_{ov})$.

$$\text{where, } v = \frac{\varepsilon_H - \varepsilon_L}{\nabla \varepsilon} + 1 \qquad (14)$$

ε_H *and* ε_L are the lowest and highest possible values and $\nabla\varepsilon$ which results in maximize the CIR for given ε.

here $\varepsilon_H = 0.25, \varepsilon_L = 0.03$ *and* $\nabla\varepsilon = 0.02$ so that v=12 to avoid the above drawbacks sub-optimal pair(λ_{so}, μ_{so}) has been found by using the following criterion

$$(\lambda_{so}, \mu_{so}) = \max_{\lambda_o, \mu_o} \left[p - \frac{\sum_{j=1}^{p} (p - CIR(\varepsilon_j, \lambda_o, \mu_o))}{v} \right] \qquad (15)$$

where p is the maximum CIR of a particular row of the matrix and second term is mean deviation of the CIR of that row from the peak (p) of that row, so here these sub-optimal values (λ_{so}, μ_{so}) independent of normalized frequency offset ε in the proposed method these values are $\lambda_{so} = 0.6164$ *and* $\mu_{so} = 1.0351$

IV. SIMULATION RESULTS AND DISCUSSION

Here we have considered an OFDM system with N=64 subcarriers and we are using MPSK modulation with M=4 is used to modulate each of the subcarrier. The simulation using MATLAB software are performed to evaluate CIR and BER performance.

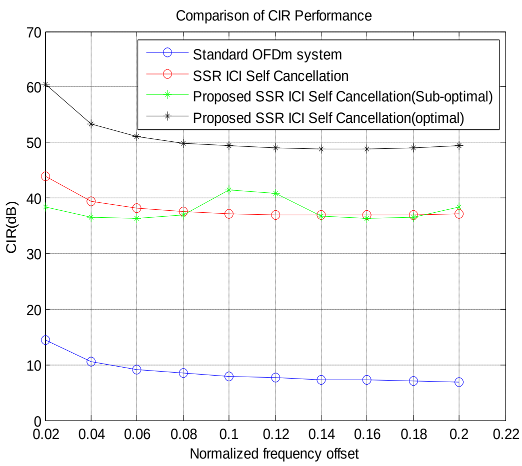
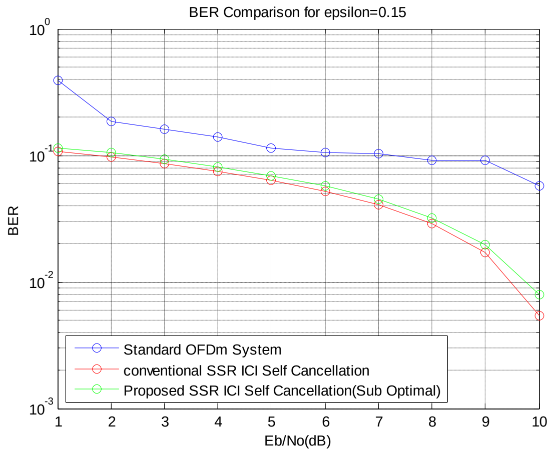


Fig 2.CIR versus Normalized frequency offset for various ICI cancellation schemes

As from the figure 2 the CIR performance of proposed system provides a gain of more than 8dB at $\varepsilon = 0.10$ over conventional scheme. But for $\varepsilon \in [0.03, 0.08]$ t he proposed scheme CIR is slightly aggravate than conventional scheme



.Fig 3. BER comparison for various schemes. The graph showing the results BER versus Eb/No (dB).

The BER performance of proposed scheme is very much improved than standard OFDM system.

V. CONCLUSION

This paper investigate the sub-optimal ICI self cancellation scheme for combating the impact of ICI on OFDM system. The proposed scheme provides significant CIR improvement, without increasing the hardware complexity and removes the requirement of CFO estimation

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